PHYTOTOXICOLOGY TECHNICAL MEMORANDUM

Phytotoxicology 2000 Investigation: Campbell and Goldcorp Mines - Balmertown

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Purpose

The purpose of this report is to document the current status of the ministry's soil sampling investigation of arsenic and metals in the Balmertown area related to gold mining activities.

Introduction

Balmertown is a small gold mining town located 430 km northwest of Thunder Bay with a population of over 1000 residents. Development of the town site started in 1943 around two gold mines, the Dickenson Mine (now the Goldcorp Mine owned by Goldcorp) and Campbell Mine (owned by Placer Dome). Today, these are the two largest gold mines in the Red Lake District of northwestern Ontario. Historically, the Placer Dome Mine has been the larger of the two mines, although recently Goldcorp has enlarged its mine following the discovery of a zone of high grade ore. Goldcorp and Placer Dome mines are adjacent to each other. The gold ore occurs in quartz carbonate veins, which contain varying amounts of sulphides including arsenopyrite. Historic releases of arsenic to the environment resulting from the ore roasting activities in Balmertown as well as from mine tailings containing arsenic have been deposited in the community. Ongoing arsenic emissions and discharges to the surrounding environment have been greatly reduced since the closing of the Dickenson roaster in 1980 and the Placer Dome roaster in 1993, as well as through improvements in tailings handling procedures. Nevertheless, elevated arsenic soil concentrations remain in the community due largely to past mining activities.

In 1994, the Ontario Ministry of the Environment (MOE) Northern Technical Support Section collected trembling aspen foliage and surface soil from a total of 42 terrestrial monitoring sites encompassing Balmertown and the surrounding Placer Dome Canada mine areas (MOE, 1994). The report from this survey concluded that arsenic levels in tree foliage declined in 1994 compared to levels in previous surveys, but remained above MOE Upper Limit of Normal Criteria. Concentrations of arsenic in surface soil exceeded MOE guidelines at all sites. There was no apparent trend in surface soil arsenic concentration over the period from 1974 to 1994. However, levels of arsenic were usually lower in subsurface soils than surface soils, which suggests the arsenic was from airborne deposition.

The highest soil arsenic concentrations have been found to be on residential properties on 6th and 7th Streets. These high arsenic concentrations were attributed to mine tailings from the Placer Dome mine that had been deposited in this area in the late 1940s and early 1950s. Evidently during that time period, tailings were piped through what is now Balmertown and dumped in a wetland south of the town. In the winter, the tailings in the pipe would freeze near the end of the pipe, so the pipeline was shortened and the tailings were deposited closer to the mine, in the area of the present day Sixth and Seventh Streets. Between 1965 and 1989, 23 homes were built on the tailings. In 1990, remedial work was performed to remove the tailings and replace them with clean fill. A subsequent investigation discovered that 11 homes were still underlain with tailings. In 1993 and 1994, Placer Dome Canada conducted a urinalysis screening program of local residents in which soil, household dust and urine samples were collected from three populations: the Balmertown study area (11 homes that had been built on arsenic contaminated tailings, located on the east side of 7th Street and the adjoining backyards on 6th Street), the Balmertown control area (residential areas of Balmertown not built on tailings), and the Red Lake Control (residential areas of the nearby community of Red Lake). Also, an exposure assessment was conducted that included the following pathways: ingestion of food, ingestion of drinking water, ingestion of soil and ingestion of dust. This assessment was composed of three parts: 1) calculation or point estimates of exposures for individual houses, 2) Monte Carlo analysis to produce a probability distribution for exposure, 3) comparison of predicted exposure to urinalysis results. In the Balmertown study area, soil arsenic concentrations ranged up to 1730 ug/g dry weight, with most concentrations less than 300 ug/g dry weight, dust concentrations ranged up to 237 ug/g dry weight and urine arsenic concentrations ranged up to 25.1 ug/l (with the health-based action level set at 50 ug/l for speciated arsenic)(Placer Dome, 1995). The primary findings of the exposure assessment were that "if all soil and dust were removed, total lifetime exposure to arsenic in the Balmertown study area would only be reduced by 3 percent. Even if the average soil and dust concentrations in the Balmertown study area were reduced by one-half, total lifetime exposure would only be reduced by 2 percent" and that "the need for soil removal to reduce arsenic exposure is not indicated"(Placer Dome, 1995).

In 1999, staff of the Ecological Standards and Toxicology Section, Ontario Ministry of the Environment repeated the soil sampling conducted by Placer Dome Canada in 1993 and 1994 (MOE, 1999). Soil samples were collected from 9 residential properties on Sixth and Seventh Streets and Dexter Road (Seventh Street area) where a range of arsenic concentrations, including some of the highest arsenic concentrations in Balmertown, had been detected. In addition, soil samples were collected from two residential properties on the edge of town, five public green spaces and the Placer Dome active tailings area west of the mine. Soil arsenic concentrations up to 2000 µg/g were found on properties in the Seventh Street area.

In 2000, the current investigation was initiated by the Thunder Bay - Kenora Area District Office of the MOE in order to determine the extent of arsenic contamination in the residential areas of Balmertown beyond the Seventh Street area.

Methods

On September 20, 2000, duplicate composite soil samples were collected from 25 residential properties by the staff of the Ecological Standards and Toxicology Section of the Ontario Ministry of the Environment (MOE). A minimum of 15 soil cores (0-5 cm deep) were collected with a hand-held soil corer by walking a "W", or "X" pattern across each yard. This process was replicated to obtain the duplicate composite soil sample. The soil cores from each duplicate soil sample were stored in new polyethylene bags and processed (air-dried, homogenized, and sieved, first through a 2mm sieve and then ground and passed through a 355µm sieve) at the Ecological Standards and Toxicology sample processing laboratory (MOE). The processed samples were forwarded to the MOE Laboratory Services Branch where they were analyzed for aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, manganese, magnesium, molybdenum, nickel, strontium, vanadium, and zinc using the MOE Laboratory Services Branch accredited analytical method E3073L1. Mercury was analyzed using the MOE Laboratory Services Branch accredited analytical method E3059L1 and antimony, arsenic, and selenium were analysed using the MOE Laboratory Services Branch accredited analytical method E3245L1.

Results and Discussion

Arsenic

In both the 1999 and 2000 soil surveys, as well as previous ministry surveys (MOE, 1994), arsenic was identified as the chemical of greatest concern due to elevated concentrations compared to background, phytotoxicity effects-based criterion and lack of MOE human health risk-based soil arsenic criterion. The current investigation entailed the sampling of soil on 25 residential properties located throughout Balmertown. This investigation was conducted to expand the area sampled in the 1999 soil survey and to provide an overall picture of soil arsenic and metal concentrations in most residential blocks of Balmertown. In contrast, the MOE soil sampling conducted in 1999 to audit the Placer Dome results, focused on the area of Sixth and Seventh Streets where the Placer Dome study had been conducted (Placer Dome, 1995).

The overall pattern of arsenic contamination in Balmerton shows the highest concentrations in the area of Sixth and Seventh Streets with soil arsenic concentrations tending to drop to background concentrations in the southern part of the town, an area farthest away from the mines and historic roasters. In the Seventh Street area, the high arsenic concentrations are attributable to the underlying tailings. Whether the high soil arsenic concentrations in other areas of Balmertown are due to tailings material is unknown. However, in general, soil arsenic concentrations are 1.5 times higher in surface soil (0-5 cm) than in soil collected at 5-10 cm, which suggests the arsenic is from aerial deposition related to historic emissions from the ore roasters and blowing soil/dust from the mine site (MOE, 1995). The contribution of blowing soil/dust from the large historic tailings areas south of the town has not been quantified and would depend on meteorological conditions, tailings cover and handling procedures, soil and dust particle size, and the physical-chemical association of arsenic to soil particles and dust. The current survey found that soil arsenic concentrations in residential properties closest to these historic tailings south of the town were among the lowest in Balmertown.

Arsenic concentrations in soil sampled from individual properties are given in Table 1 (2000 data) and Table 2 (1999 data). In the 1999 data, over 90% of the residential properties had soil arsenic concentrations exceeding the MOEE (1997) Table A effects-based criterion for plants (see Appendix A). This largely reflects the selection of properties with high arsenic concentrations for auditing purposes in 1999. It should be noted that for arsenic, the Table A guideline is based on injury to plants, which are considered sensitive terrestrial receptors. The ministry does not have a Table A soil arsenic guideline based on human health. In 2000, approximately half (52%) of the 25 residential properties sampled had soil As concentrations above the MOE Table A guideline. These data provide an overall indication of the arsenic levels in residential soils of this community.

Soil Arsenic Availability and Toxicity

Concentrations reported by the ministry are for total arsenic or total metal concentrations in soil; no distinction is made of the possible chemical forms of each element (e.g., soil arsenic speciation or soil metal speciation). Some forms of arsenic such as sodium arsenite, hydroy-dimethylarsine oxide and monosodium methanearsonate are known for their toxicity to plants and have been used as herbicides, desiccants and soil sterilants (Woolson and Isensee, 1981). Inorganic arsenic is a human carcinogen via long-term drinking water exposure and via occupational inhalation exposure of air-borne arsenic; however, certain organic arsenic compounds, such as arsenobetaine in seafood, are less metabolized and more rapidly eliminated in urine than inorganic forms (IPCS, 2001). Generally, in well aerated soils, arsenic is present in the arsenate form (Woolson et al., 1973). The MOEE (1997) Table A soil criterion is based on scientific studies investigating the effect of sodium arsenate on plant species. In contrast, the arsenic in mine tailings of the nearby Campbell Mine in Balmertown is primarily in the arsenopyrite [FeAsS] form in the flotation tailings and in hematite [α-Fe_2O_3] and maghemite [γ-Fe_2O_3] forms in the oxidized residue from the roaster (McCreadie et al., 2000). Although the release of arsenic from these tailings changes with oxidation- reduction reactions down through the tailings, the arsenic on the surface where plants might grow is relatively unavailable. Other factors including soil pH, soil texture, organic content, iron content, redox potential and microbial activity affect the availability of arsenic in soils and the uptake of arsenic into plants. Additional information on arsenic speciation is required to resolve the issue of arsenic availability in soils and mine tailings.

Plant Observations

Ministry investigators during the current survey noted that local vegetation in the areas with known historic tailings material lacked obvious signs of arsenic toxicity, such as blackened roots and leaf margins, which suggests that arsenic in the tailings may be less available for plant root uptake despite elevated concentrations.

According to a resident of Stovel Ave., garden plants periodically suffered severe damage due to emissions from the ore roasters when they were operating but lawn areas were not as affected. Some grasses are known to be tolerant of arsenic, such as Agrostis tenuis, Agrostis stolonifera and Agrostis canina (Benson et al., 1981). The fern (Pteris vittata) is not only tolerant of arsenic, but accumulates arsenic and is being used to remediate arsenic contaminated sites (Tu and Ma, 2002). Nevertheless, many plants such as green beans and spinach are very sensitive to arsenic in soil (Woolson, 1973). It has been concluded that it is rare that arsenic accumulations in plants reach levels that are harmful to animals and man because invariably, growth is reduced before the content will reach toxic levels (Peterson et al., 1981). This statement is based on a study involving the arsenic content and growth reduction in radish, spinach, green beans, cabbage, lima beans and tomato (Woolson, 1973).

Arsenic and Human Health

The ministry does not have a Table A soil arsenic criterion that is human health risk-based (MOEE, 1997). However, screening criteria for arsenic levels in soils have been derived by other regulating bodies with a range of about one thousand-fold difference among them (see Table 3). These differences in soil screening criteria for arsenic are due to differences in assumptions regarding the mechanism of carcinogenicity (linear non-threshold genotoxicity *vs* non-linear threshold non-genotoxicity) and life-stage and exposure characteristics of individual receptor of concern (e.g. child or adult). All regulatory bodies base the arsenic hazard assessments on results of epidemiology studies of a Taiwanese population exposed to high arsenic levels in their drinking water. No adjustments have been made in the derivation of these generic soil screening criteria to account for differences in the oral bioavailability of arsenic in soils versus that of arsenic in the Taiwanese drinking water studies. Generic soil screening criteria are derived assuming 100% oral bioavailability. However, the measured oral bioavailability of arsenic in soil has been determined in animal feeding studies to range from 0.26% to 68% of soluble inorganic arsenic controls (Ellickson et al., 2001; Freeman et al., 1995; Freeman et al, 1993; Groen et al., 1994; Ng and Moore 1996; Ng et al. 1998; Roberts et al., 2002; USEPA, 1996). Data on the availability of arsenic in soil needs to be considered in assessing human uptake of As from soil (IPCS, 2001) and is likely site-specific.

Due to the highly conservative assumptions used to derive of the human health risk-based Generic Soil Screening Criteria of CCME and US EPA, these criteria for soil arsenic (Table 3) are several orders of magnitude less than typical surface soil concentrations of arsenic in Ontario soils of 14-17 ug As/g soil (MOEE, 1993). This confounds the usefulness of CCME and US EPA Generic Arsenic Soil Screening values for the identification of areas that may be of human health concern due to soil arsenic levels. It has been estimated that the relative contribution to total daily arsenic exposure of Canadians that is attributable to soils is minor, < 1%, as compared to other sources of exposure notably food and water (CANTOX 1999; CEPA, 1993). Furthermore the relevance of human epidemiology studies, specifically the Taiwanese drinking water exposure and occupational inhalation exposure related to copper smelters, to the assessment of health effects of soil arsenic is uncertain. It is concluded that the toxicity of arsenic in drinking water cannot be directly extrapolated to assess the toxicity of soil arsenic due to differences in the chemical speciation, bioavailability, and excretion kinetics (Valberg et al., 1997).

Metals

Nickel concentrations were found to be elevated above background concentrations (Table F, see Appendix B) on some residential properties (Tables 1 and 2). Also, antimony concentrations were above background soil concentrations on many properties and exceeded the MOE Table A criterion for human health threshold non-cancer effects of antimony in soils sampled from 6 of the residential yards in 1999 and 2000. The antimony concentrations on these 6 properties also have the potential to cause adverse effects to sensitive plant species. On all properties with elevated antimony concentrations, arsenic concentrations were also elevated.

The other metals listed in Tables 1 and 2 did not exceed concentrations listed in MOE Soil Criteria, Tables A and F. Several metals including beryllium, cadmium, lead, mercury, molybdenum and selenium, soil concentrations were either at trace levels (<T) or not detectable with the analytical methods used (≤W).

Conclusions

Arsenic concentrations in Balmertown residential soils were found to be elevated above background levels sufficient to warrant further investigation. Elevated levels of arsenic in soils were found throughout the community, with approximately half of the properties sampled in 2000 having total arsenic concentrations above the ministry's phytotoxicity effects-based criterion. The highest soil arsenic concentrations detected in the 1999 and 2000 investigations were in the area of Sixth and Seventh Streets and appeared to be associated with historic tailings materials, but high arsenic concentrations were not confined to this area. In general, soil arsenic concentrations decreased with increasing distance from the mines. Further study would be required to determine the availability of elevated soil arsenic for plant uptake and the potential for human exposure and any related health risks to the community related to elevated soil arsenic concentrations.

Nickel and antimony were the only other elements detected at concentrations above background and the ministry's phytotoxicity effects-based criteria. Although soil nickel concentrations on some sites were above typical Ontario background concentrations, the levels were not above ministry effects-based criterion for either human health or plant toxicity and therefore were not considered to be of concern. Antimony concentrations in soils of some residential properties were above ministry effects-based criterion for both human health and plant toxicity indicative of potential human health and ecological concern.

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Table 1: Elemental concentrations (µg/g) in surface soil samples collected from residential properties in Balmertown, Ontario

Site Numbers	Location	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron
Site 62	Front Lawn	5900	1	0.9	44	0.5	0.5	8900	16	4	18	8100
Site 62	Front Lawn	5600	1	1	37	0.5	0.3	7800	22	4.2	16	8900
Site 63	Front Lawn	6000	**1.3**	16	36	0.5	0.2	7700	25	4.9	36	9900
Site 63	Front Lawn	5800	**1.2**	14	33	0.5	0.2	5900	28	5	27	11000
Site 64	Front Lawn	740	0.9	15	45	0.5	0.4	6200	24	6.2	25	12000
Site 64	Front Lawn	7900	1	**21**	48	0.5	0.3	7300	26	6.2	29	13000
Site 65	Front Lawn	8200	**1.3**	13	52	0.5	0.2	5800	24	6.1	14	13000
Site 65	Front Lawn	9800	**1.4**	16	61	0.5	0.2	6200	27	7.3	17	14000
Site 66	Front Lawn	4600	**3.8**	**47**	54	0.5	0.9	12000	21	4.5	28	8100
Site 66	Front Lawn	4800	**3.1**	**39**	49	0.5	0.6	11000	22	4.6	23	9800
Site 67	Front Lawn	4400	**1.8**	**21**	33	0.5	0.3	5500	18	4.4	13	7900
Site 67	Front Lawn	4000	**1.6**	14	28	0.5	0.3	5100	18	3.4	11	9800
Site 68	Front Lawn	6300	**1.5**	17	42	0.5	0.6	6600	23	4.1	17	9800
Site 68	Front Lawn	6200	**1.2**	15	34	0.5	0.5	5200	25	4.3	14	10000
Site 69	Front Lawn	11000	**4.6**	**160**	68	0.5	0.7	8400	35	10	37	17000
Site 69	Front Lawn	11000	**4.6**	**140**	70	0.5	0.5	9200	33	9.8	33	16000
Site 70	Front Lawn	4600	0.8	14	58	0.5	0.2	12000	13	3.1	22	6700
Site 70	Front Lawn	4000	**1.7**	12	41	0.5	0.3	8600	12	2.7	16	6600
Site 71	Front Lawn	11000	**27**	**330**	93	0.5	0.7	13000	39	14	46	18000
Site 71	Front Lawn	11000	**25**	**320**	89	0.5	0.9	13000	41	14	46	19000
Site 72	Front Lawn	10000	**7.5**	**160**	77	0.5	0.8	14000	36	10	39	17000
Site 72	Front Lawn	11000	**7**	**170**	82	0.5	0.5	15000	40	11	41	18000
Site 73	Front Lawn	8100	**14**	**150**	58	0.5	0.4	10000	37	9.6	29	16000
Site 73	Front Lawn	9400	**14**	**170**	72	0.5	0.3	12000	41	11	33	16000
Site 74	Front Lawn	10000	**5.3**	**120**	76	0.5	0.6	11000	39	9	33	16000
Site 74	Front Lawn	8300	**4.2**	**120**	55	0.5	0.4	8400	33	7.5	26	14000
T		1000	1	1	5	2.5	1	500	5	2.5	5	1000
W		200	0.2	0.2	1	0.5	0.2	100	1	0.5	1	200
Table F*		27000	1	17	210	1.2	1	58000	71	21	85	33000
Table A†		NG	13	20	1000	1.2	12	NG	1000	50	300	NG

* Table F - Background surface soil criteria (MOE guideline) for residential land use. Where no Table F value was available, the OTR$_{98}$ value for old urban parkland was substituted and is shown in italics (see Appendix B)

† Table A - Effects-based surface soil remediation criteria (MOE guideline) for residential sites in a potable groundwater situation (see Appendix A)

NG - no guideline, values ≤W - no measurable response, values <T - trace amount; interpret with caution

Values in bold and underlined exceed the MOE effects-based guidelines (Table A)

Values in bold exceed the MOE background-based guidelines (Table F)

Table 1 continued: Elemental concentrations (µg/g) in surface soil samples collected from residential properties in Balmertown, Ontario

Site Numbers	Location	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron
Site 75	Front Lawn	11000	**1.2**	**22**	75	0.5	0.5	8100	31	8.4	27	17000
Site 75	Front Lawn	11000	**1.2**	**27**	82	0.5	0.4	9300	31	8.4	32	17000
Site 75	Garden	9900	**2.2**	**35**	130	0.5	0.8	17000	45	6.4	24	14000
Site 75	Garden	9800	**2.4**	**32**	120	0.5	0.6	16000	43	7	23	14000
Site 76	Front Lawn	6600	**2.5**	**34**	66	0.5	0.4	16000	20	5.6	20	11000
Site 76	Front Lawn	7700	**3.3**	**92**	71	0.5	0.6	15000	23	5.8	23	12000
Site 77	Front Lawn	12000	**33**	**420**	89	0.5	0.4	9400	33	14	50	18000
Site 77	Front Lawn	10000	**27**	**440**	69	0.5	0.8	7600	30	10	37	18000
Site 78	Front Lawn	5100	**5.8**	**110**	42	0.5	0.3	6600	17	4.4	23	8300
Site 78	Front Lawn	4600	**3.5**	**62**	28	0.5	0.3	4600	14	3	14	9200
Site 79	Front Lawn	14000	**16**	**280**	100	0.5	0.9	15000	47	13	48	21000
Site 79	Front Lawn	12000	**9.4**	**140**	82	0.5	0.7	13000	44	11	36	18000
Site 80	Front Lawn	4300	0.6	8.5	27	0.5	0.6	4400	20	3.4	13	9600
Site 80	Front Lawn	4400	0.7	8.1	29	0.5	0.7	4700	20	3	14	9800
Site 80	Garden	9000	**2.6**	**36**	79	0.5	0.2	10000	25	6.9	21	14000
Site 80	Garden	9200	**3.2**	**59**	80	0.5	0.4	11000	26	7	23	14000
Site 81	Front Lawn	7000	0.9	14	52	0.5	0.4	6800	25	5.6	20	12000
Site 81	Front Lawn	6900	0.7	9.3	51	0.5	0.3	6500	23	5.7	19	12000
Site 82	Front Lawn	3700	0.6	8.9	26	0.5	0.7	4400	15	4.1	19	8900
Site 82	Front Lawn	4000	0.7	7.3	31	0.5	0.3	5200	16	4	24	9300
Site 83	Front Lawn	4800	**1.1**	11	30	0.5	0.4	4500	18	4.1	26	11000
Site 83	Front Lawn	4100	0.6	7.8	27	0.5	0.3	3800	14	3.7	23	7600
Site 84	Front Lawn	5800	0.2	5.3	40	0.5	0.2	9000	31	5.7	15	11000
Site 84	Front Lawn	5800	0.2	4.9	42	0.5	0.2	9900	30	5.5	14	12000
Site 85	Front Lawn	14000	**20**	**440**	44	0.5	0.5	20000	62	16	40	30000
Site 85	Front Lawn	15000	**20**	**460**	42	0.5	0.2	18000	64	17	37	31000
Site 86	Front Lawn	16000	**17**	**440**	63	0.5	0.4	16000	58	17	42	32000
Site 86	Front Lawn	14000	**14**	**330**	72	0.5	0.5	15000	48	14	40	27000
T		1000	1	1	5	2.5	1	500	5	2.5	5	1000
W		200	0.2	0.2	1	0.5	0.2	100	1	0.5	1	200
Table F*		27000	1	17	210	1.2	1	58000	71	21	85	33000
Table A†		NG	13	20	1000	1.2	12	NG	1000	50	300	NG

* Table F - Background surface soil criteria (MOE guideline) for residential land use. Where no Table F value was available, the OTR$_{98}$ value for old urban parkland was substituted and is shown in italics (see Appendix B)

† Table A - Effects-based surface soil remediation criteria (MOE guideline) for residential sites in a potable groundwater situation (see Appendix A)

NG - no guideline, values ≤W - no measurable response, values <T - trace amount; interpret with caution

Values in bold and underlined exceed the MOE effects-based guidelines (Table A)

Values in bold exceed the MOE background-based guidelines (Table F)

Table 1 continued: Elemental concentrations (µg/g) in surface soil samples collected from residential properties in Balmertown, Ontario

Site Numbers	Location	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
Site 62	Front Lawn	8	3000	160	0.02	0.6	12	0.3	21	19	30
Site 62	Front Lawn	10	3300	150	0.02	0.6	13	0.2	18	20	31
Site 63	Front Lawn	15	3100	220	0.03	0.5	15	0.2	24	24	38
Site 63	Front Lawn	10	2900	200	0.02	1.8	17	0.2	20	26	30
Site 64	Front Lawn	10	3800	220	0.03	0.6	16	0.2	22	29	33
Site 64	Front Lawn	9	4100	240	0.03	0.5	17	0.2	24	31	35
Site 65	Front Lawn	10	4000	210	0.01	0.5	15	0.2	21	32	33
Site 65	Front Lawn	11	4800	240	0.02	0.5	18	0.2	22	36	37
Site 66	Front Lawn	9	3300	300	0.12	0.9	17	0.4	26	20	59
Site 66	Front Lawn	14	3500	270	0.07	0.6	17	0.5	25	22	52
Site 67	Front Lawn	12	2200	230	0.07	0.5	10	0.2	17	17	31
Site 67	Front Lawn	12	2000	210	0.04	0.5	10	0.2	17	22	27
Site 68	Front Lawn	11	2700	240	0.03	0.5	13	0.3	20	23	42
Site 68	Front Lawn	6	2500	190	0.03	0.5	14	0.3	18	25	35
Site 69	Front Lawn	40	5100	310	0.06	0.6	33	0.3	25	43	77
Site 69	Front Lawn	31	5000	320	0.07	0.7	30	0.3	28	41	73
Site 70	Front Lawn	5	2400	140	0.03	0.6	11	0.5	29	14	34
Site 70	Front Lawn	8	2000	110	0.02	0.7	9.1	0.5	22	15	23
Site 71	Front Lawn	56	6200	440	0.16	0.6	**46**	0.4	33	39	110
Site 71	Front Lawn	66	6300	430	0.21	0.6	**46**	0.4	31	40	110
Site 72	Front Lawn	33	6200	330	0.07	0.5	34	0.4	30	39	100
Site 72	Front Lawn	38	6600	360	0.07	0.6	39	0.4	31	41	98
Site 73	Front Lawn	41	4900	290	0.09	0.5	35	0.3	24	33	67
Site 73	Front Lawn	43	5600	320	0.09	1.1	38	0.3	27	36	78
Site 74	Front Lawn	30	5300	310	0.06	0.5	34	0.4	29	38	71
Site 74	Front Lawn	25	4300	250	0.06	0.5	28	0.3	24	34	57
T		10	250	25	0.05	2.5	2.5	1	5	5	25
W		2	50	5	0.01	0.5	0.5	0.2	1	1	5
Table F*		120	16000	1300	0.23	2.5	43	1.9	78	91	160
Table A†		200	NG	NG	10	40	200	10	NG	250	800

* Table F - Background surface soil criteria (MOE guideline) for residential land use. Where no Table F value was available, the OTR$_{98}$ value for old urban parkland was substituted and is shown in italics (see Appendix B)

† Table A - Effects-based surface soil remediation criteria (MOE guideline) for residential sites in a potable groundwater situation (see Appendix A)

NG - no guideline

Values ≤W - no measurable response, values <T - trace amount; interpret with caution

Values in bold and underlined exceed the MOE effects-based guidelines (Table A)

Values in bold exceed the MOE background-based guidelines (Table F)

Table 1 continued: Elemental concentrations (µg/g) in surface soil samples collected from residential properties in Balmertown, Ontario (2000)

Site Numbers	Location	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
Site 75	Front Lawn	16	5900	320	0.03	0.5	24	0.2	23	39	60
Site 75	Front Lawn	17	6100	340	0.03	0.5	25	0.2	25	40	55
Site 75	Garden	21	5000	540	0.04	0.9	20	0.6	50	37	100
Site 75	Garden	22	4900	520	0.05	0.6	20	0.6	47	36	100
Site 76	Front Lawn	14	4600	240	0.04	0.7	16	0.6	34	26	51
Site 76	Front Lawn	14	4800	240	0.04	0.5	19	0.5	35	29	55
Site 77	Front Lawn	60	4300	380	0.27	1	40	0.4	29	36	140
Site 77	Front Lawn	46	3700	280	0.17	0.5	32	0.3	23	34	110
Site 78	Front Lawn	16	2500	270	0.09	0.5	15	0.2	21	19	50
Site 78	Front Lawn	6	2000	180	0.07	0.5	10	0.2	16	20	31
Site 79	Front Lawn	55	7200	480	0.12	0.8	**44**	0.3	35	49	120
Site 79	Front Lawn	42	6000	380	0.09	0.5	38	0.3	31	43	89
Site 80	Front Lawn	10	2100	130	0.02	0.5	9.9	0.2	16	24	26
Site 80	Front Lawn	7	2100	140	0.03	0.5	10	0.2	15	25	30
Site 80	Garden	10	4900	340	0.03	0.5	17	0.2	32	34	60
Site 80	Garden	13	5100	340	0.04	0.5	18	0.2	32	34	64
Site 81	Front Lawn	12	3900	240	0.03	0.5	17	0.2	20	31	39
Site 81	Front Lawn	12	3800	230	0.03	0.5	16	0.2	20	29	36
Site 82	Front Lawn	14	1900	220	0.03	0.5	8.6	0.2	16	21	30
Site 82	Front Lawn	8	2100	270	0.04	0.5	9.3	0.2	17	22	35
Site 83	Front Lawn	12	2300	230	0.02	0.5	13	0.2	18	25	30
Site 83	Front Lawn	12	2000	190	0.02	0.5	9.9	0.2	15	18	27
Site 84	Front Lawn	9	4400	180	0.02	0.5	34	0.2	25	28	25
Site 84	Front Lawn	6	4700	200	0.02	0.5	17	0.2	27	29	25
Site 85	Front Lawn	17	10000	680	0.1	0.6	**67**	0.3	36	69	83
Site 85	Front Lawn	17	9900	690	0.11	0.5	**68**	0.3	33	72	81
Site 86	Front Lawn	16	9900	750	0.13	0.5	**61**	0.3	31	71	120
Site 86	Front Lawn	11	8600	630	0.13	0.5	**51**	0.3	32	61	100
T		10	250	25	0.05	2.5	2.5	1	5	5	25
W		2	50	5	0.01	0.5	0.5	0.2	1	1	5
Table F*		120	16000	1300	0.23	2.5	43	1.9	78	91	160
Table A[†]		200	NG	NG	10	40	200	10	NG	250	800

* Table F - Background surface soil criteria (MOE guideline) for residential land use. Where no Table F value was available, the OTR_{98} value for old urban parkland was substituted and is shown in italics (see Appendix B)

† Table A - Effects-based surface soil remediation criteria (MOE guideline) for residential sites in a potable groundwater situation (see Appendix A)

NG - no guideline, values ≤W - no measurable response, values <T - trace amount; interpret with caution

Values in bold and underlined exceed the MOE effects-based guidelines (Table A)

Values in bold exceed the MOE background-based guidelines (Table F)

Table 2: Elemental concentrations (µg/g) in surface soil samples collected from residential properties in Balmertown, Ontario (1999)

Site Numbers	Location	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron
Site 25	Aspen near garage	14000	**2.4**	**67**	69	0.5	0.2	6800	43	9.9	23	21000
Site 34	Baseball diamond	13000	0.7	7.6	104	0.5	0.4	59000	28	6.2	19	14000
Site 43	Hill south of centre	3800	0.3	6.5	39	0.5	0.2	5100	10	2.1	6	7000
Site 44	South of play area	4300	0.4	9.7	31	0.5	0.3	6300	15	2.5	12	7100
Site 46	Outdoor rink	14000	**7.4**	**165**	84	0.5	0.2	7700	33	11	29	20000
Site 48	Back Lawn	20000	**4.8**	**225**	115	0.5	0.3	13000	55	14	35	27000
Site 49	Back Lawn	8900	**3.9**	**100**	48	0.5	0.3	7100	30	6.8	19	16000
Site 50	Back Lawn	9000	**3.4**	**115**	46	0.5	0.3	7600	29	7.2	19	17000
Site 51	Back Lawn	12000	**2.8**	**90**	76	0.5	0.4	10000	39	9.2	44	21000
Site 52	Back Lawn	9500	**1.6**	18	71	0.5	0.3	8500	31	6.9	29	15000
Site 53	Back Lawn	14000	**2.2**	**41**	87	0.5	0.7	8400	43	8.9	24	20000
Site 54	Side Lawn	14000	**4.7**	**145**	74	0.5	0.5	11000	48	12	28	22000
Site 55	Back Lawn	9500	**5.9**	**300**	35	0.5	0.2	8900	40	8.3	20	20000
Site 56	Back Lawn	24000	**51**	**1850**	75	0.5	0.8	21000	87	32	67	54000
Site 57	Front Lawn	3200	0.5	7.2	14	0.5	0.2	3000	13	2.3	6.5	8200
Site 58	Front Lawn	14000	**3.1**	**110**	90	0.5	0.2	10000	41	9.5	28	21000
T		1000	1	1	5	2.5	1	500	5	2.5	5	1000
W		200	0.2	0.2	1	0.5	0.2	100	1	0.5	1	200
Table F*		27000	1	17	210	1.2	1	58000	71	21	85	33000
Table A†		NG	13	20	1000	1.2	12	NG	1000	50	300	NG

* Table F - Background surface soil criteria (MOE guideline) for residential land use. Where no Table F value was available, the OTR$_{98}$ value for old urban parkland was substituted and is shown in italics (see Appendix B)

† Table A - Effects-based surface soil remediation criteria (MOE guideline) for residential sites in a potable groundwater situation (see Appendix A)

NG - no guideline

Values ≤W - no measurable response, values <T - trace amount; interpret with caution

Values in bold and underlined exceed the MOE effects-based guidelines (Table A)

Values in bold exceed the MOE background-based guidelines (Table F)

Table 2 continued: Soil elemental concentrations from the 1999 sampling of selected residential properties in Balmertown, Ontario

Site	Location	Lead	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Strontium	Vanadium	Zinc
Site 25	Aspen near garage	8	6000	375	0.02	0.7	31	0.2	27	49	45
Site 34	Baseball diamond	6	13000	275	0.02	0.5	19	0.4	180	37	49
Site 43	Hill south of centre	2.5	1700	94	0.02	0.5	5.7	0.2	20	17	16
Site 44	South of play area	3	2400	135	0.02	0.5	8.1	0.2	22	17	26
Site 46	Outdoor rink	15	6500	375	0.06	0.5	33	0.2	27	42	86
Site 48	Back Lawn	16	9400	530	0.07	0.5	42	0.3	37	61	95
Site 49	Back Lawn	9.5	4700	255	0.04	0.5	20	0.2	22	39	47
Site 50	Back Lawn	6.5	5200	285	0.04	0.5	22	0.2	20	38	51
Site 51	Back Lawn	35	6800	350	0.04	0.7	29	0.2	26	44	130
Site 52	Back Lawn	15	5300	245	0.01	0.5	19	0.2	25	36	51
Site 53	Back Lawn	8.5	6900	355	0.02	0.5	27	0.2	28	52	61
Site 54	Side Lawn	13	7900	410	0.13	0.5	38	0.2	28	51	89
Site 55	Back Lawn	7	5300	410	0.06	0.5	31	0.2	23	45	53
Site 56	Back Lawn	29	14000	1400	0.28	0.5	**115**	0.2	41	**101**	**235**
Site 57	Front Lawn	2.5	1400	72	0.01	0.5	5.5	0.2	14	20	12
Site 58	Front Lawn	35	7000	425	0.06	0.5	29	0.2	38	50	65
T		10	250	25	0.05	2.5	2.5	1	5	5	25
W		2	50	5	0.01	0.5	0.5	0.2	1	1	5
Table F*		120	16000	1300	0.23	2.5	43	1.9	78	91	160
Table A†		200	NG	NG	10	40	200	10	NG	250	800

* Table F - Background surface soil criteria (MOE guideline) for residential land use. Where no Table F value was available, the OTR$_{98}$ value for old urban parkland was substituted and is shown in italics (see Appendix B)

† Table A - Effects-based surface soil remediation criteria (MOE guideline) for residential sites in a potable groundwater situation (see Appendix A)

NG - no guideline

Values ≤W - no measurable response, values <T - trace amount; interpret with caution

Values in bold and underlined exceed the MOE effects-based guidelines (Table A)

Values underlined values exceed the MOE background-based guidelines (Table F)

Table 3: Human Health Risk-Based Criteria for Arsenic in Soil

Jurisdiction	**Human Health Risk-Based Soil As Criteria**	**Basis**[a]	**Reference**
Ontario	none		MOE Table A Soil Remediation Criteria
Canada	All land uses 12 ug/g 31 ppm 220 ppm	Lifetime incremental risk > background of 10^{-6}; 10^{-5}, 10^{-4} + 10 ug/g (average background soil As level); adult; soil ingestion rate = 0.02 g/d; exposure term = 1.	CCME 1995
US	SSL= 0.427 ug/g	soil ingestion; adult male (age-adjusted soil ingestion factor = 114 mg-yr/kg-d); carcinogen; exposure 30y over an averaging period of 70y and cancer risk 10^{-6}	USEPA, 1996
UK	SGV residential= 20 ug/g commercial/industrial = 200 ug/g	Monte Carlo 95th percentile exposure of child ingestion of soil and home garden; oral index dose = 0.3 ug/kg bw/d estimated from WHO drinking water guideline 10ug/L based on skin effects in Taiwanese. Based on total inorganic As in sandy soil pH 6-8.Commercial/industrial assumes lifetime exposure of indoor adult workers doing office/light work.	Dept. for Environment, Food and Rural Affairs, The Environment Agency, 2002
Netherlands	IV all land uses = 678 mg/kg	soil ingestion, crops and inhalation of soil-dust. Inorganic As considered to be a threshold substance TDI = 2.1 ug/kg bw/d. Lifetime averaging of exposure.	RIVM, 1994 cited in Dept. for Environment, Food and Rural Affairs, The Environment Agency, 2002.
	proposed HH SRC = 576 mg/kg	Propose TDI = 1 ug/kg bw/d; lifetime exposure	RIVM, 2001 Dept. for Environment, Food and Rural Affairs, The Environment Agency, 2002.

[a] All protocols assume 100% oral bioavailability of soil inorganic arsenic.

Appendix A
Derivation and Significance of the MOE Soil Clean-up Guidelines

The MOE soil clean-up *Guidelines* have been developed to provide guidance for cleaning up contaminated soil. The *Guidelines* are not legislated Regulations. Also, the *Guidelines* are not action levels, in that an exceedence does not automatically mean that a clean-up must be conducted. The *Guidelines* were prepared to help industrial property owners decide how to clean-up contaminated soil when property is sold and/or the land-use changes. Most municipalities insist that contaminated soil is cleaned up according to the MOE *Guidelines* before they will approve a zoning change for redevelopment, therefore, even though the *Guideline* is voluntary most industrial property owners and developers are obliged to use it. For example, the owner of an industrial property who plans to sell the land to a developer who intends to build residential housing can use the *Guideline* to clean up the soil to meet the residential land-use criteria. In this way previously-contaminated industrial land can be re-used for residential housing without concern for adverse environmental effects.

The *Guideline* contains a series of Tables (A through F), each having criteria for soil texture, soil depth, and ground water use for various land-use categories (eg, agricultural, residential, industrial). Table F *criteria* reflect the upper range of background concentrations for soil in Ontario. An exceedence of Table F indicates the likely presence of a contaminant source. Tables A through E *criteria* are effects-based and are set to protect against the potential for adverse effects to human health, ecological health, and the natural environment, whichever is the most sensitive. By protecting the most sensitive parameter the rest of the environment is protected by default. The *Guideline criteria* take into consideration the potential for adverse effects through direct contact, and through contaminant transfer from soil to indoor air, from ground water or surface water through release of volatile gases, from leaching of contaminants in soil to ground water, or from ground water discharge to surface water. However, the *Guideline criteria* ***may not*** ensure that corrosive, explosive, or unstable soil conditions will be eliminated.

If the decision is made that remedial action is needed, the *criteria* in Tables A to F of the *Guideline* can be used as clean-up targets. In some cases, because of economic or practical reasons, it may not be possible to clean up a site using the generic *criteria* in Tables A to F. The *Guideline* provides a process, called a *site specific risk assessment*, which is used to evaluate the soil contamination with respect to conditions that are unique to the contaminated site. In a *site specific risk assessment* the proponent examines all the potential pathways through which the contamination may impact the environment and must demonstrate that because of conditions unique to that site the environment and human health will not be adversely effected if contamination above the generic *criteria* in Table A to E is left in place.

When contamination is present and a change in land-use is not planned, for example residential properties and public green spaces near a pollution source, the *Guideline* may be used in making decisions about the need for remediation. This is different from the previously described situation where a company that caused contamination on their own property decides to clean up the soil, usually at the insistence of the municipality who will not approve a zoning change unless remediation is conducted. Decisions on the need to undertake remedial action when the *Guideline criteria* are exceeded ***and*** where the land-use is not changing are made on a site by site basis using *site specific risk assessment* principals and are usually contingent on the contaminants having caused an adverse environmental effect or there is a demonstrated likelihood that the contamination may cause an adverse effect. Because of the long history of industrial operation and our practice of living close to our work place the soil in many communities in Ontario is contaminated above the effects-based *criteria* in the MOE *Guidelines*. In practice, remediation of contaminated soil on privately-owned residential property and public green spaces has only been conducted in communities when the potential for adverse health effects has been demonstrated.

The soil clean-up *Guidelines* were developed from published U.S. EPA and Ontario environmental data bases. Currently there are criteria for about 25 inorganic elements and about 90 organic compounds. Criteria were developed only if there were sufficient, defendable, effects-based data on the potential to cause an adverse effect. All of the criteria address human health and aquatic toxicity, but terrestrial ecological toxicity information was not available for all elements or compounds. The development of these clean-up *Guidelines* is a continuous program, and criteria for more elements and compounds will be developed as additional environmental data become available. Similarly, new information could result in future modifications to the existing *Guidelines*.

For more information on the MOE's soil clean-up *Guidelines* please refer to the *Guideline for Use at Contaminated Sites in Ontario. Revised February 1997*, Ontario Ministry of Environment and Energy, PIBs 3161E01, ISBN 0-7778-6114-3.

Appendix B
Derivation and Significance of the MOE "Ontario Typical Range" Soil Guidelines.

The MOE "Ontario Typical Range" (OTR) guidelines are being developed to assist in interpreting analytical data and evaluating source-related impacts on the terrestrial environment. The OTRs are used to determine if the level of a chemical parameter in soil, plants, moss bags, or snow is significantly greater than the normal background range. An exceedence of the OTR_{98} (*the* OTR_{98} *is the actual guideline numbe*r) may indicate the presence of a potential point source of contamination.

The OTR_{98} represents the expected range of concentrations of chemical parameters in surface soil, plants, moss bags, and snow from areas in Ontario not subjected to the influence of known point sources of pollution. The OTR_{98} represents 97.5 percent of the data in the OTR distribution. This is equivalent to the mean plus two standard deviations, which is similar to the previous MOE "Upper Limit of Normal" (ULN) guidelines. In other words, 98 out of every 100 background samples should be lower than the OTR_{98}.

The OTR_{98} may vary between land use categories even in the absence of a point source of pollution because of natural variation and the amount and type of human activity, both past and present. Therefore, OTRs are being developed for several land use categories. The three main land use categories are Rural, New Urban, and Old Urban. Urban is defined as an area that has municipal water and sewage services. Old Urban is any area that has been developed as an urban area for more than 40 years. Rural is all other areas. These major land use categories are further broken into three subcategories; Parkland (which includes greenbelts and woodlands), Residential, and Industrial (which includes heavy industry, commercial properties such as malls, and transportation rights-of-way). Rural also includes an Agricultural category.

The OTR guidelines apply only to samples collected using standard MOE sampling, sample preparation, and analytical protocols. Because the background data were collected in Ontario, the OTRs represent Ontario environmental conditions.

The OTRs are not the only means by which results are interpreted. Data interpretation should involve reviewing results from control samples, examining all the survey data for evidence of a pattern of contamination relative to the suspected source, and where available, comparison with effects-based guidelines. The OTRs are particularly useful where there is uncertainty regarding local background concentrations and/or insufficient samples were collected to determine a contamination gradient. OTRs are also used to determine where in the anticipated range a result falls. This can identify a potential concern even when a result falls within the guideline. For example, if all of the results from a survey are close to the OTR_{98} this could indicate that the local environment has been contaminated above the *anticipated average,* and therefore the pollution source should be more closely monitored.

The OTRs identify a range of chemical parameters resulting from natural variation and normal human activity. ***As a result, it must be stressed that values falling within a specific*** OTR_{98} ***should not be considered as acceptable or desirable levels; nor does the*** OTR_{98} ***imply toxicity to plants, animals or humans.*** Rather, the OTR_{98} is a level which, if exceeded, prompts further investigation on a case by case basis to determine the significance, if any, of the above normal concentration. Incidental, isolated or spurious exceedences of an OTR_{98} do not necessarily indicate a need for regulatory or abatement activity. However, repeated and/or extensive exceedences of an OTR_{98} that appears to be related to a potential pollution source does indicate the need for a thorough evaluation of the regulatory or abatement program.

The OTR_{98} supersedes the Phytotoxicology ULN guideline. The OTR program is on-going. The number of OTRs will be continuously updated as sampling is completed for the various land use categories and sample types. For more information on these guidelines please refer to *Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags, and Snow. MOEE Report Number HCB-151-3512-93, PIBs Number 2792, ISBN 0-778-1979-1.*